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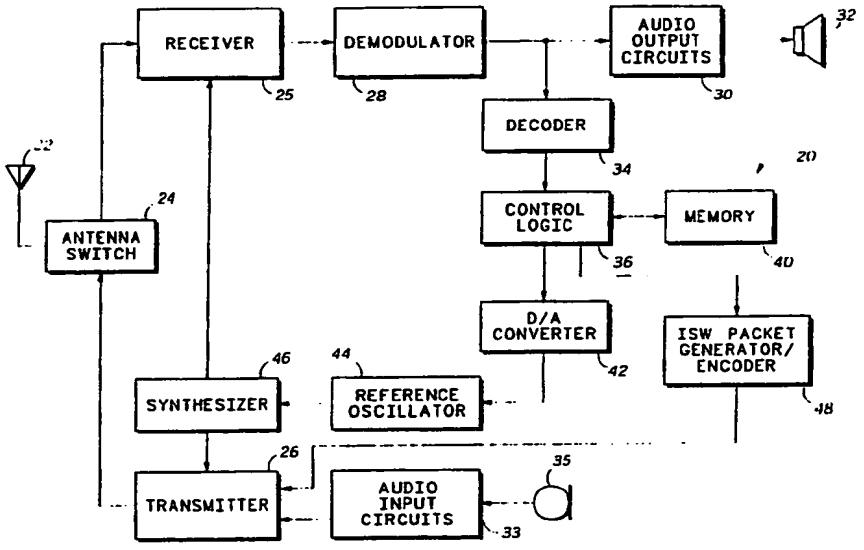

(57) Abstract

A radio communication system including a control station and at least one remote station (20) is provided. The control station has a receiver for receiving radio signals, a transmitter for transmitting radio signals and a demodulator for measuring the frequency of the received signals. Responsive to a request for frequency measurement received from the receiver, the control station also has an error signal encoder to provide an error feedback signal containing the polarity and magnitude of the frequency difference for transmission by the transmitter. At least one remote station (20) has a receiver (25), a transmitter (26), a frequency controller (46), an encoder for encoding the request for frequency measurement and for actuating the transmitter (26) to transmit the request, and a decoder (34), responsive to the received error feedback signal for adjusting the frequency control.

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RADIO FREQUENCY ERROR DETECTION AND CORRECTION SYSTEM

BACKGROUND OF THE INVENTION

This is a continuation-in-part of application Serial No. 7/413,144, filed September 27, 1989. This invention relates to a two-way radio communication system, in general, and particularly to a system in which the frequency of radios utilized in the system can be remotely adjusted.

In radio communication systems, the operating frequency of the radios must be maintained within specified limits according to federal regulations (FCC rules). Radios are adjusted for correct operating frequencies at the time of manufacture. However, the aging of components can result in changes in the operating frequency of the radio. Additionally, portable radios are likely to be carried between markedly different thermal environments and thus experience a higher rate of frequency change than fixed stations.

While many two-way radios are now utilizing a frequency synthesizer rather than discrete channel elements for each frequency of operation, it is necessary to maintain the proper reference frequency for the frequency synthesizer. It has conventionally been necessary to remove a radio from service in order for the radio to be tested and adjusted as required on a

reference frequency for the frequency synthesizer. It has conventionally been necessary to remove a radio from service in order for the radio to be tested and adjusted as required on a periodic basis. This approach is undesirable for a number of reasons. Not only is a radio unavailable for use when it is in the shop being adjusted, the process is also expensive as it requires a trained technician to make the necessary adjustments. It is therefore desirable that the radio be adjusted without removing it from operation and without the intervention of a trained technician.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a means such that on request from a remote unit, a control station will generate a digital frequency magnitude and polarity error message to correct the frequency of the remote unit.

Another aspect of the invention is to provide a means to avoid adjacent channel interference due to radios transmitting "off frequency". In one embodiment of the invention, an oscillator is provided which includes an electronic frequency adjustment network plus a digital memory element such as an EEPROM which is used to digitally set the oscillator frequency upon receiving a correction command in response to a request to the control station.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a two-way radio system in accordance with the present invention.

FIG. 2 is a block diagram of a remote two-way radio of FIG. 1.

FIG. 3 is a schematic of a reference oscillator of the two-way radio of FIG. 2.

FIG. 4 is a block diagram of a control station of FIG. 1.

FIG. 5 is a block diagram of a frequency calibration source for use by the central controller in a trunking system.

FIG.s 6a-b are simplified flow diagrams of the signal processing in the receiver site controller to calibrate a repeater.

FIG. 7 are illustrations of the signalling formats in accordance with the present invention.

FIG. 8 is a detailed block diagram of the control logic 81 of FIG. 4.

FIG. 9 illustrates the contents of the memory 79 of FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a two-way radio system in accordance with the present invention is illustrated. A control or central station 10 is utilized in conjunction with a plurality of remote two-way radios 20. The control station 10 can be a base station, a repeater connected to a central controller, or as is discussed below, can be part of a trunked radio communication system. The remote radios 20 can be any combination of portables, mobiles, or base stations capable of communication with the control station 10.

Referring to FIG. 2, a detailed block diagram of a remote two-way radio 20 in accordance with the present invention is illustrated. Each radio 20 includes an antenna 22 operatively coupled, via an antenna switch 24, to either a receiver section 25 or a transmitter section 26. As is known, the antenna switch 22 may be replaced by a duplexer. A demodulator or discriminator 28, coupled to the output of the receiver section 25, has its output coupled to audio output circuits 30 in a conventional manner for FM frequency to voltage translation or discrimination. The output of audio circuits 30 is applied to a transducer such as a speaker 32.

The output of demodulator 28 is also applied to a decoder 34 which, in turn, is coupled to a control logic 36. In the preferred embodiment, the decoder 34 and control logic 36 are preferably implemented in a microprocessor or microprocessor, but can be discrete circuitry. The control logic 36 communicates with a memory 40, which in a preferred embodiment includes an EEPROM that serves as the radio's code plug (non-volatile memory). As is conventional, the memory 40 would also include a RAM and a ROM. An output of the control logic 36 is connected

to a digital to analog (D/A) converter 42 which provides a bias voltage for controlling the frequency of a reference oscillator 44. The oscillator 44 provides the reference frequency signal for a synthesizer 46. The local oscillator signals for both the receiver section 25 and transmitter section 26 are provided by the synthesizer 46 in a conventional manner. A microphone 35 is connected via audio input circuits 33 to the transmitter section 26. As is conventional, the control logic 36 also has control lines, not shown, which connect to the audio circuits 30 and 33, the synthesizer 46, the receiver section 25, the transmitter section 26, the antenna switch 24, and the microphone 35.

Another output of the control logic 36 couples to an ISW packet generator or encoder 48 which in turn is connected to the transmitter 26. The encoder 48 generates a digital signal or data message packet called an inbound signalling word (ISW) 710 which is shown in FIG. 7.

Referring to FIG. 7, to exchange information in a trunked system, a subscriber unit or radio 20 sends a data packet called an "in-bound signalling word" (ISW) 710 to the control station 10. The ISW includes synchronization bits 712, a requesting unit's unique ID code 906 and a data message 716 such as a frequency error measurement request in accordance with the present invention. The ISW 710 is forwarded to the central controller or control station 10 which decodes the request and transmits a data packet called an "out-bound signalling word" (OSW) 750. The OSW is also a data packet having synchronization bits 752, the requesting unit's ID code 906, a digital frequency error message 903 including for example, an error sign bit 756 and error magnitude bits 758, and other message bits 907.

Referring now to FIG. 3, a schematic diagram of the reference oscillator 44 of the two-way radio 20 is illustrated. This reference oscillator 44 may commonly be recognized as a voltage controlled oscillator. An amplifier 50 and a resistor 52 are both connected in parallel across a crystal 54. A capacitor 56 is connected between one side of the crystal 54 and ground while a

capacitor 58 is connected between the other side of the crystal 54 to ground. A B+ voltage is supplied via an RF choke 60 to the junction of the crystal 54 and the capacitor 58. An anode of a varactor diode 62 is also connected to this junction of the RF choke 60 and the crystal 54. A capacitor 64 is connected between the cathode of varactor 62 and ground. The cathode of varactor 62 is connected to the output of the D/A converter 42 of FIG. 2.

The amplifier 50 provides the gain for the reference oscillator circuit 44. The feedback portion of the oscillator circuit consists of the resistor 52, the crystal 54, the varactor 62 and the capacitors 56, 58, and 64. The output of the D/A converter 42 along with the B+ bias voltage control the capacitance of varactor 62 in order to warp or change the frequency of the oscillator 44.

Referring to FIG. 4, a block diagram of the control station 10 in accordance with the present invention is illustrated. The control station 10 can be a base station or, as illustrated here, a repeater. An antenna 62 of the repeater 10 is coupled via a duplexer 64 to a receiver section 65 and a transmitter section 66. A master oscillator 68 provides the reference frequency signal for a receiver synthesizer 70 and a transmitter synthesizer 71 which are connected to the receiver section 65 and transmitter section 66, respectively.

A demodulator 72 is coupled to the output of the receiver section 65 and has its output coupled to audio circuits 74. The output of the demodulator 72 is also applied to an analog to digital (A/D) converter 78 which provides a digital signal for the control logic 81 and serves to digitize received signals output from the demodulator 72. Preferably, the control logic is implemented in a microprocessor or microcontroller along with the A/D 78 and together, they comprise an error signal detector and encoder means.

Referring to FIG. 8, a more detailed block diagram of the control logic 81 is shown. An arithmetic logic unit (ALU) 88 receives the digitized signal from the A/D 78 and processes it in the ALU 88. If not used for frequency error measurement, then

the processed inbound signalling word ISW packet 710 is sent to an ISW packet decoder 87. An outbound signalling word (OSW 750) packet generator or encoder 83 generates a digital packet from the outputs of the ISW packet decoder 87 and the ALU 88 in conjunction with a memory 79. The contents of the memory 79 are more clearly shown in FIG. 9 and will be described in more detail later.

Referring back to FIG. 4, an output of the control logic 81 (the encoder 83 output of FIG. 8) is connected to a data filter 82 which, in turn, is coupled to the input of a summer 84. Another input of the summer is coupled to the output of the audio circuits 74. The output of the summer 84 is applied to a modulator 86 and then to the transmitter section 66 for transmission in a conventional manner.

In normal operation, the control logic 36 of radio 20 generates a predetermined setting for the reference oscillator 44. This setting is also stored in the memory 40. In order to provide the reference frequency for the synthesizer 46, the D/A converter 42 converts this setting into a bias voltage for controlling the frequency of the reference oscillator 44. According to the invention, the remote radio 20 transmits a data message packet signal requesting frequency measurement of the reference oscillator 44 along with its identification address 906 (in what could be an Inbound Signalling Word (ISW) 710 if the radio is in a trunking environment).

At the control station 10, the demodulator 72 receives the transmitted packet request 710 which is then decoded in the decoder 87. After waiting a short time period before measuring the frequency, the control logic 81 checks the response of a signal strength detector (not shown) in the receiver 65 to determine if the signal is strong and clean enough to measure. Additionally, other checks to ensure a quality correction process can be optionally implemented in the control logic 81.

If the received signal is good, frequency measurement can proceed. By averaging the data stream received, the central station or control station 10 measures the frequency by using the

analog to digital converter 78 to convert the transmitted waveform into digitized data usable by the arithmetic logic unit (ALU) 88 and stored in the memory 79. This data may be used for decoding purposes as well as frequency measurement purposes.

In a frequency shift keying (FSK) system, the average value of the waveform corresponds to the average frequency of the transmitted data packet. This is calculated in the ALU 88 of FIG. 8 by adding the digitized waveform values 900 and dividing by the number of waveform data values. This waveform averaged value can then be used to compare each particular waveform value to determine the FSK digital signal pattern to be decoded.

In general, the signal pattern may not be symmetrical and result in a non-zero waveform average value even if the transmitted frequency were the correct frequency. This non-symmetry may be eliminated by choosing a symmetrical pattern or adding a compensation digital word 901 to produce a resultant null for the proper transmitted frequency. Either method will result in a waveform averaged value which correctly represents the remote unit's average transmission frequency.

The ALU result which corresponds to the average frequency received, is retained as a first digital word. Another previously stored digital value, labeled as a second digital word 902, representing the value expected or predetermined for the correct frequency (assuming no receiver tuning, calibration, or other errors) is subtracted from the first digital word in the ALU 88 and the difference is stored as a third digital word 903 in the memory 79 representing the sign and magnitude of the error. This digital error word 903 may be formatted as an actual magnitude representation, a closest stepsize or combination of different stepsizes corresponding to the magnitude, or may be, but not limited to, a representation of the number of incremental correction levels needed for correcting substantially the full magnitude of the error in one step.

The control logic 81 also determines whether the error is too small or too large for the remote unit to correct. Under the condition that the frequency error can and should be corrected,

this digital error word 903 is then sent by the ALU 88 for assembly into a packet with other information and encoded by the encoder 83 with other information into a digital data feedback error signal 750 which is transmitted back to the remote radio for corrective action via the modulator 86 and the transmitter 26.

Also stored in the memory 79 are two additional digital words: a fourth digital word 904 representing the magnitude of the minimum correctable error, and a fifth digital word 905 representing the magnitude of the maximum correctable error. If the magnitude of the error word 903 lies within the minimum/maximum range, than the data signal packet 750 containing the sign and magnitude of the error is transmitted to the remote radio as stated above. If the magnitude of the error word 903 is less than the magnitude of the minimum correctable error (904), no correction is necessary and optionally this error signal may be transmitted to the remote radio but no corrective action taken. On the other hand, when the magnitude of the error word 903 exceeds the magnitude of the maximum correctable error (905), the remote radio may be commanded to shut down and transmission inhibited. As a further option, the control logic 81 can generate a command for transmission to the remote unit to re-try frequency correction. If the verification is unsuccessful once too often, the control logic 81 may provide a disable remote radio command instead of generating the data signal for frequency correction. In addition, an alert signal either audible or visual may be generated along with the disabling command. These command signals along with the identification (ID) of the remote radio to be corrected may be incorporated in a digital data message packet (Outbound Signalling Word (OSW) 750 for a trunking application). The identifier was assembled by the packet generator 83 receiving the ID code 906 which was stored there by the ALU 88 when the ISW 710 was decoded by the packet decoder 87.

In response, the remote radio 10, after matching the encoded transmitted word ID with its own identification or address, adjusts its reference oscillator 44. The demodulator 28

recovers the encoded error signal from the receiver output and feeds the information into the decoder 34. Based on the decoded data and control information, the control logic 36, if necessary, changes the value in the memory 40 and outputs a corresponding digital word for the D/A converter 42 to change the reference oscillator 44 in the proper polarity and amount in order to arrive at the proper frequency in one step. As previously described, the voltage thus generated by the digital to analog converter 42 is placed across the varactor 62 to maintain within specified limits the frequency of the synthesizer 46 by overcoming the frequency error.

Referring to FIG. 5, one embodiment of the radio communications system of the present invention is illustrated. The control station 10 of FIG. 4 comprises a central controller 202 coupled to one of a plurality of repeaters 201. In this trunked communication system, the plurality of repeaters 201 each includes a receiver R1-R5 and a transmitter T1-T5. In normal operation, one repeater operates as one control channel to receive inbound and transmit outbound signalling words, and the other repeaters are used for trunked voice and data communications relay, all under the supervision of a central site controller 320.

For frequency calibration operations, each repeater has added circuitry to defeat normal repeater operation and is connected to the external frequency calibration source 108 under the supervision of the central site controller 320. The purpose of the frequency calibration is to assure the accuracy of the second digital word 902 which is used as the reference for remote frequency measurement by the receiver site controller 314 used in the control station 10. If multiple control channels were utilized, calibration would be performed on each control channel repeater and a separate calibration word would be stored for each channel.

The central controller 202 is coupled to the plurality of trunked repeaters 201 via a receive data bus 112 and a transmit data bus 114. The frequency calibration source is coupled to

each of the trunked repeaters 201 upon inputs from the control lines (CCI) and the mute lines. The central controller 202 is further comprised of an inbound recovery board (IRB) 310, one or more receiver interface boards (RIB) 312, a receiver site controller (RSC) 314, a transmit site controller (TSC) 316, a transmit interface board (TIB) 318, and a central site controller (CSC) 320. To process the received Inbound Signalling Words (ISW)s and channel information from the frequency calibration source, the RSC 314 containing at least the control logic 81 and the A/D 78 is coupled to the CSC 320.

The above mentioned modules are shown in U. S. Patent number 4,698,805 and more fully described in Motorola Instruction Manual 68P81066E60-O, entitled "Trunked Radio System Central Controller", which are hereby incorporated by reference. The Motorola manual is available from the Service Publications Department of Motorola, Inc., 1301 East Algonquin Road, Schaumburg, Ill., 60196.

In operation, a repeater calibration procedure is initiated when the central system controller 320 generates a "Frequency Calibration" command to the receiver site controller 314 to suspend normal ISW decoding of peripheral information such as identification of the remote unit 20. With this command, the control (CCI) and mute lines connect the calibration source 108 to the repeater (R1-R5) currently designated as the control channel for the control station to be calibrated. The external calibration source 108 generates a calibration signal by operating on the remote units' transmission frequency (currently the trunking control channel).

The calibration procedure is similar to the functions described for frequency measurement of a remote station 20 at the control station 10 in FIG. 4. However, here, the receiver site controller 314 including the control logic 81 performs the steps of frequency calibration where the repeater 210 couples the calibration frequency 108 to simulate the proper or expected frequency transmitted by a remote radio. As before, within the RSC controller 314, the analog-to-digital converter 78 and the

control logic 81 with associated memory 79 are used to measure the frequency error between the average frequency received (which should be the calibration frequency) represented by the first digital word, and the proper frequency represented by the second digital word 902 containing the value expected for the proper frequency associated with the frequency calibration source and is already stored in memory in the receiver site controller 314. The main variation is that now the control station itself is being measured, as referenced by the calibration source frequency, instead of the remote unit 20 and the second digital word 902 stored in the memory 79 of the control station 10 will be corrected rather than the frequency error of a remote unit. Preferably there is no correction of the given control channel of a control station; if the frequency of the given control channel of the control station exceeds the correctable limits, a different control channel or control station would then be selected.

Referring to FIG.s 6a-b, a simplified flow diagram of the signal processing in the receiver site controller 314 is illustrated to calibrate the control station. A "frequency calibration" command generated by the central site controller 320 is received at a block 802 and passed to a timer block 804 to keep track of the total elapsed time available for calibration. To keep track of the time between retries, the routine proceeds to another counter in a block 805. Upon entry, this retry counter 805 is always initialized to zero. As part of the normal ISW decoding procedure, the average A/D value (which is the average frequency received after being converted into the first digital word by the A/D converter) is computed in a block 806, after which, a block 808 suspends the rest of the normal ISW decoding procedure. The second digital word 902 representing the proper frequency already stored in the memory 79 and retrieved in step 810 is subtracted in a block 812 from the value computed in the block 806. A decision 814 determines whether the difference from the block 812 is greater than a predetermined allowable limit. If the difference is within the allowable limit, the routine proceeds to block 816 to store the measured average of block 806 as the new

proper frequency value which is now the value representing the proper frequency after calibrating out or compensating for receiver tuning or other incongruities such as A/D sensitivities in block 810 at both the repeater and the receiver site controller. After storage, the routine proceeds to a block 822 to remove the frequency source and resume normal ISW decoding in a block 818.

On the other hand, if the error difference in the block 814 is greater than the allowable limit, the routine proceeds to a decision 820 which determines whether the total allowable time for calibration has expired. If time has expired, the routine exits to the block 822 where the frequency source will be removed and normal decoding resumed (818). The routine exits at this point to continue normal communication processing.

Otherwise referring to FIG. 6b, the routine proceeds to a decision 824 which determines whether this is a second attempt at calibration. An affirmative decision from the decision block 824 transfers program control to a decision 826 to determine whether the current control channel has just been changed. If the channel is new, the routine proceeds to a block 828 to send an error message to a system manager before removing the external source (822) and resuming normal decoding (818). Otherwise, if the channel is not new, the routine proceeds to a block 830 to change the control channel to another repeater. To re-try at calibration, the routine returns to the beginning of the routine via a block 805'. On the other hand, a negative decision from the decision block 824 will enable the routine to proceed to a block 832 where the frequency measurement will be disabled. To determine whether the minimum time between retries has been reached, the routine proceeds to a decision 834. If not enough time has elapsed yet, the routine returns to block 832. Otherwise, the routine returns to the block 805' to retry calibration.

From the above description, it is clear that the invention involves a method of requesting frequency correction including the steps of receiving the request, generating the correction commands and decoding the commands to correct the frequency

of the remote unit (or the stored reference value of the repeater). Furthermore, this method provides safeguards to guarantee a certain confidence level that the corrected frequency is indeed correct. The foregoing thus describes a system and method for measuring and keeping routine ISW's to an accuracy sufficient to avoid adjacent channel interference.

In summary, a remote radio (or the control system controller) requests a frequency correction. The control station measures the frequency by averaging the data stream received. If necessary, a signal is transmitted containing the measurement resultant. In response, the remote radio (or the repeater stores a new reference value) adjusts its reference oscillator. However, if the frequency error cannot be corrected, the remote radio (or the repeater) may be commanded to shut down and transmission therefrom is inhibited.

We claim:

Claims:

1. A radio communication system comprising:

a control station having

receiver means for receiving radio signals having a frequency error,

transmitter means for transmitting radio signals,

frequency measuring means for measuring said received signals, and

error signal encoder means to provide a feedback error signal including a representation of the polarity and magnitude of the frequency error for transmission by said transmitter means, responsive to a request for frequency measurement received from said receiver means and said frequency measuring means; and

at least one of a plurality of remote stations having

receiver and transmitter means,

frequency control means containing said frequency error,

means for encoding said request for frequency measurement and for actuating said transmitter means to transmit said request including said frequency error, and

frequency error correction means, responsive to said feedback error signal for adjusting said frequency control means to correct for said polarity and magnitude of the frequency error.

2. The radio communication system of claim 1 wherein at least one of said plurality of remote stations further comprises identification signal means for actuating said transmitter means to send a unique remote station identification signal to said control station in conjunction with said request for frequency measurement.

3. The radio communication system of claim 1, wherein

said frequency measuring means comprises means for measuring a difference between a predetermined proper frequency and an averaged received signal frequency related to an output of an oscillator of at least one of said remote stations;

said error signal encoder means comprises error determination means, responsive to said frequency measuring means, to produce therefrom a digital signal having an encoded polarity and magnitude representing said difference; and

said frequency error correction means comprises a digital to analog (D/A) converter, responsive to said digital signal for generating an output voltage having a polarity and magnitude indicative of said difference, and means for applying a control output voltage to control a frequency of said oscillator.

4. The radio communication system of claim 1 wherein said error signal encoder means detects a pre-determined limit of correction being reached when a correction needed is too large to be corrected and provides a disable signal for transmission by said transmitter means to disable transmission by said remote station in response thereto.

5. The communication system of claim 4, wherein at least one of said plurality of remote stations further comprises an alert means for generating a distinct signal in response to receiving said disabling signal.

6. The communication system of claim 1, wherein said control station further comprises a signal strength detector means for determining a transmission quality of said received signals.

7. The communication system of claim 1, wherein at least one of said plurality of remote stations further comprises a programmed memory for storing a value which is used for controlling said frequency control means.

8. The communication system of claim 1, further comprising:

a local oscillator for at least one of said plurality of remote stations including

a reference oscillator having an output for providing a local oscillator output, and

frequency synthesizing means driven by said reference oscillator and having an input for receiving data signal directing said synthesizing means for production of at least one output at a frequency different than the frequency of said output of said reference oscillator, and means for applying said one different frequency output signal to said frequency control means.

9. The communication system of claim 1, wherein said frequency measuring means comprises:

means for measuring a difference between a predetermined proper frequency and a received signal frequency, said received signal frequency is related to an output of an oscillator of at least one of said remote stations to provide said radio signal.

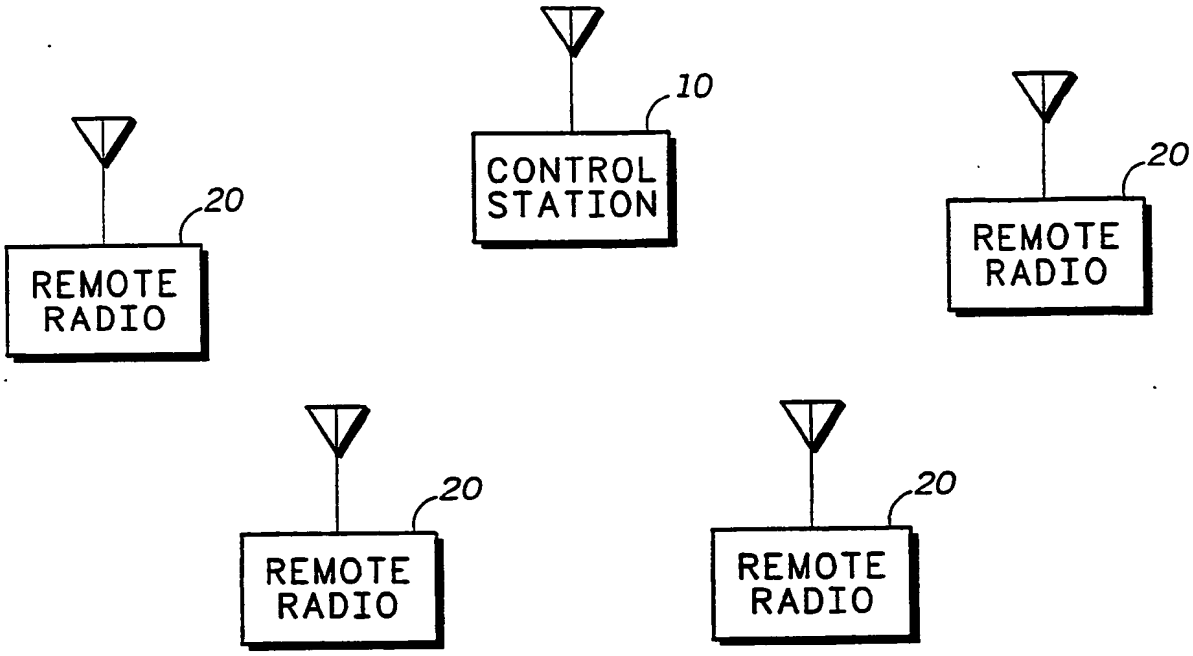
10. The communication system of claim 1, wherein said error signal encoder means comprises:

averaging means, responsive to an output of a local oscillator of said control station, for producing a signal indicative of the average frequency received;

an analog to digital converter for converting said signal indicative of the average frequency received into a first digital word;

memory means for proper storing of a second digital word representing a predetermined proper frequency; and

an analog to digital converter and logic means for comparing said first and second digital words to result in a third digital word having a sign and magnitude representing a frequency error between said average frequency received and said proper frequency for providing said frequency error signal.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REMOTE RADIO
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REMOTE RADIO
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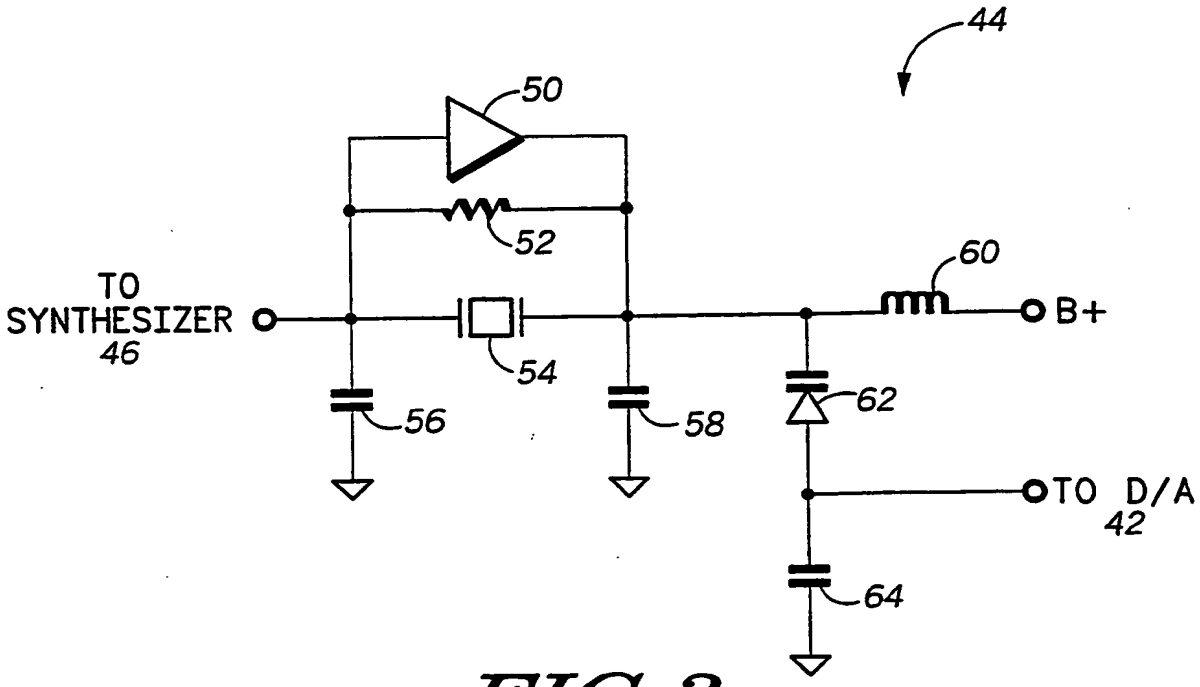
REMOTE RADIO
20
REMOTE RADIO

FIG.1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B+
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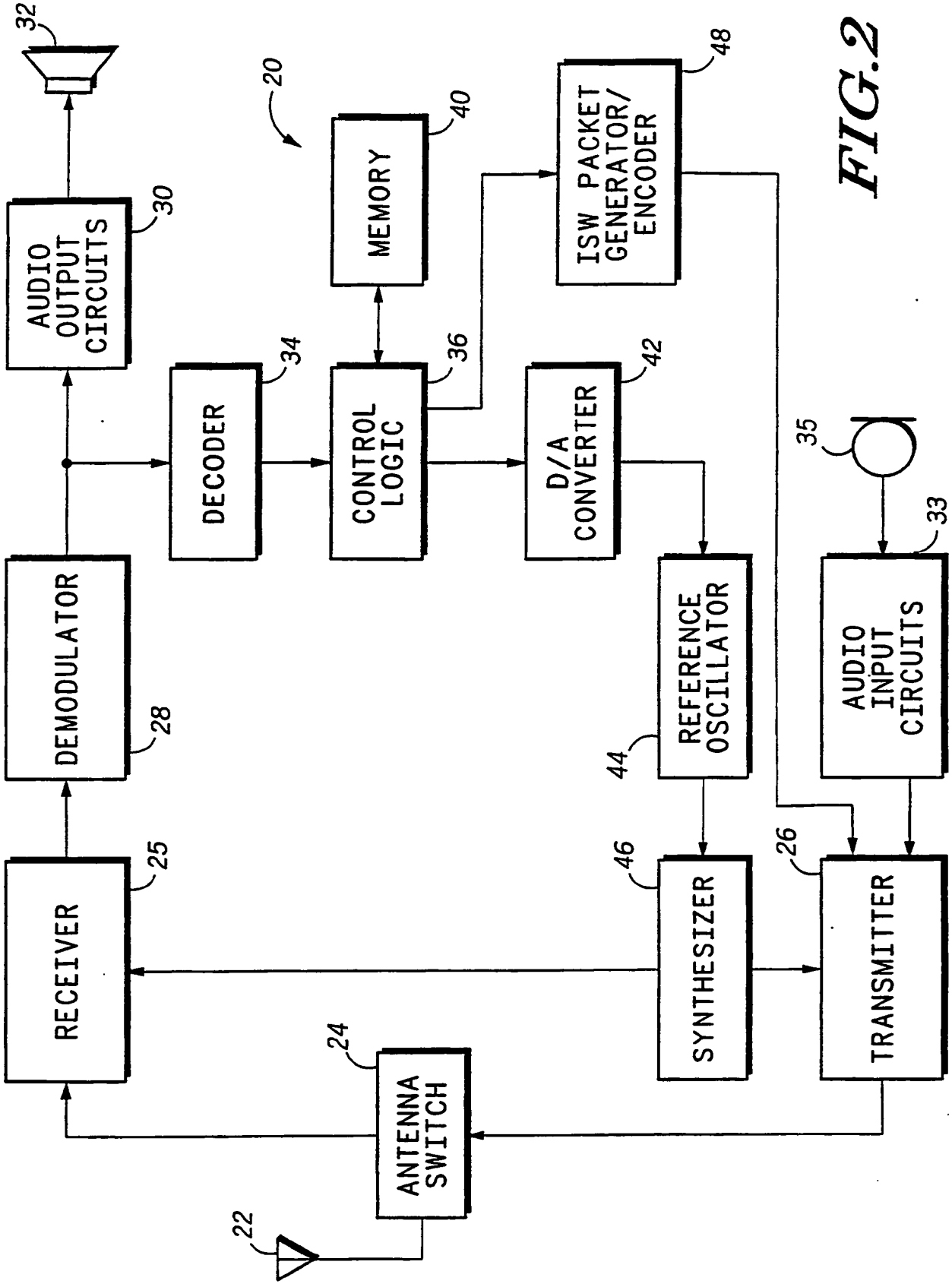
56
58
62
TO D/A 42
64

FIG.3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33
AUDIO INPUT CIRCUITS
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DEMODULATOR
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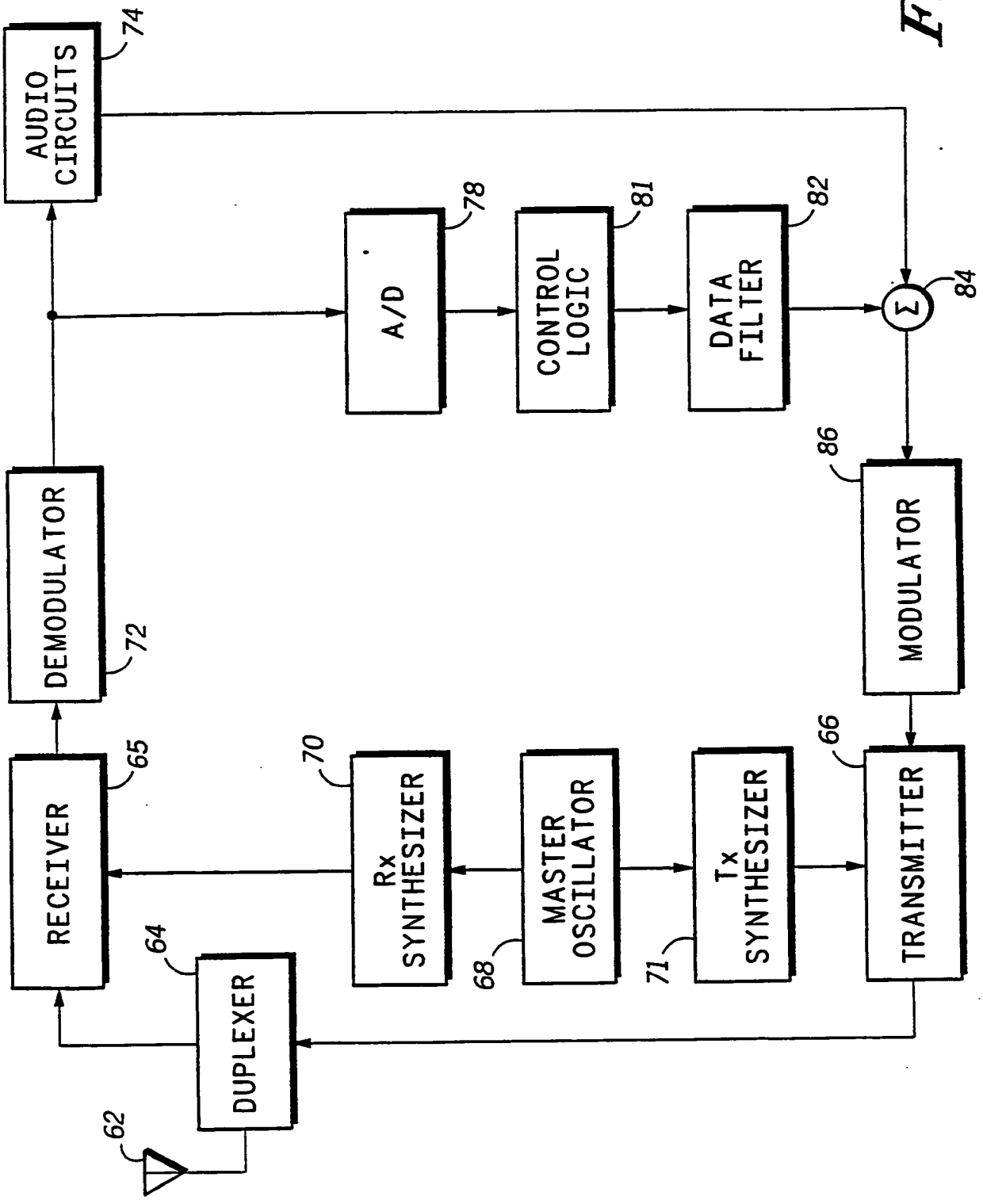
FIG.2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65
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MASTER OSCILLATOR
68
Tx SYNTHESIZER
71
TRANSMITTER
66
DUPLEXER
64
62

FIG. 4

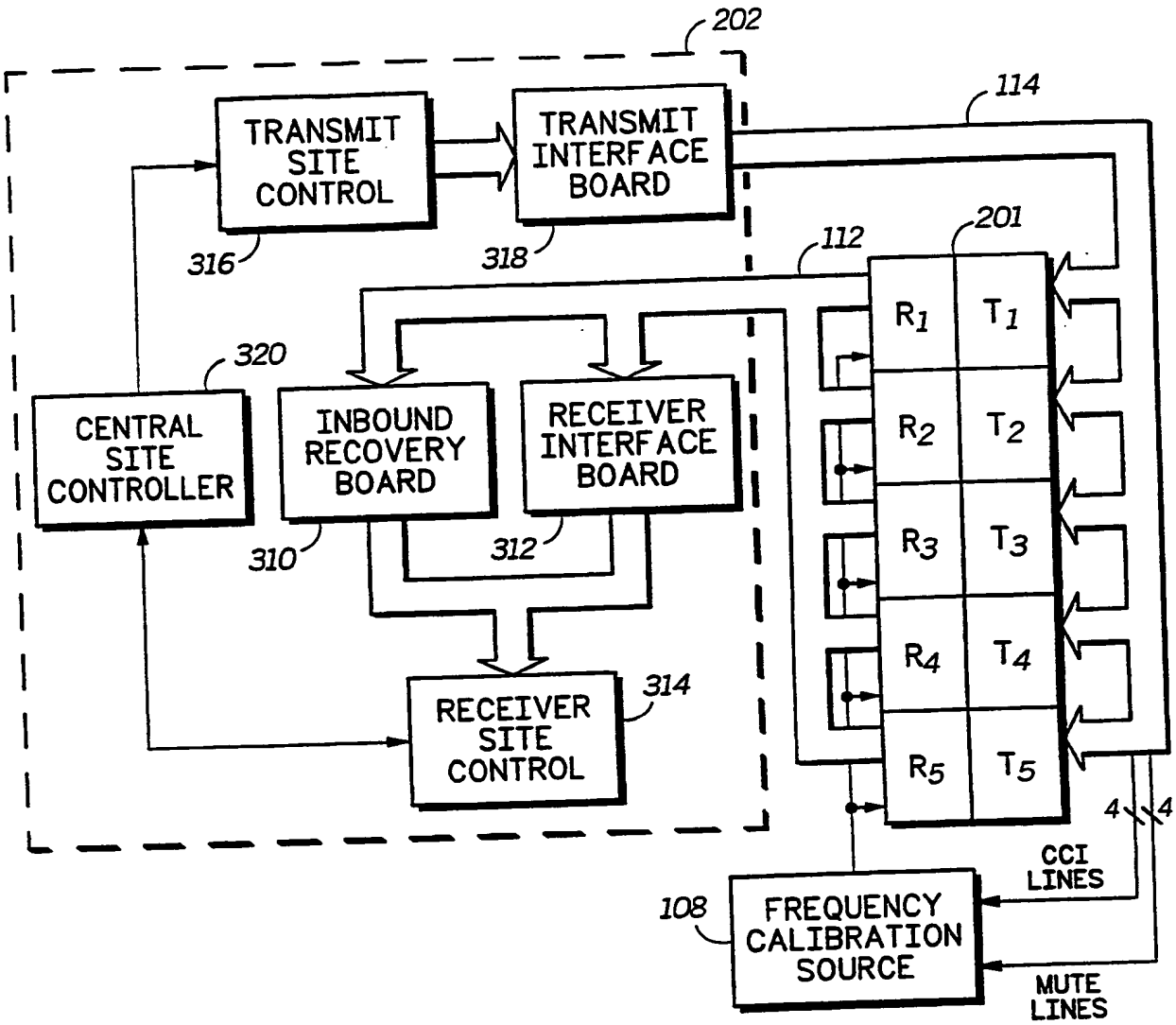
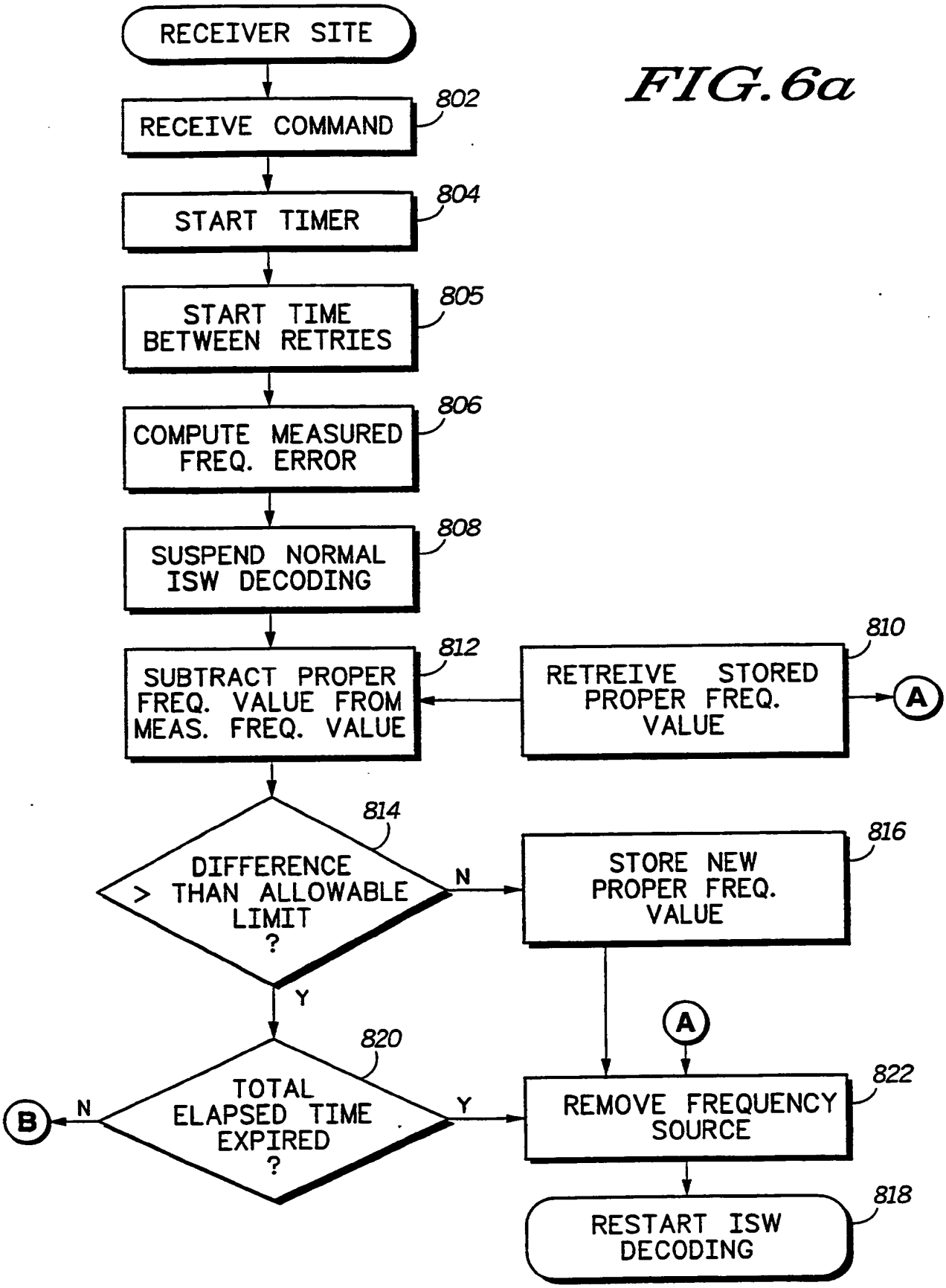

202
114
TRANSMIT SITE CONTROL
TRANSMIT INTERFACE BOARD
316
318
112
201
R1
T1
R2
T2
R3
T3
R4
T4
R5
T5
320
CENTRAL SITE CONTROLLER
INBOUND RECOVERY BOARD
RECEIVER INTERFACE BOARD
310
312
314
RECEIVER SITE CONTROL
4
4
CCI LINES
108
FREQUENCY CALIBRATION SOURCE
MUTE LINES

FIG.5

FIG. 6a


RECEIVER SITE
RECEIVE COMMAND
802
START TIMER
804
START TIME BETWEEN RETRIES
805
COMPUTE MEASURED FREQ. ERROR
806
SUSPEND NORMAL ISW DECODING
808
SUBTRACT PROPER FREQ. VALUE FROM MEAS. FREQ. VALUE
812
RETREIVE STORED PROPER FREQ. VALUE
810
A
DIFFERENCE > THAN ALLOWABLE LIMIT ?
814
N
STORE NEW PROPER FREQ. VALUE
816
Y
A
TOTAL ELAPSED TIME EXPIRED ?
820
B
N
Y
REMOVE FREQUENCY SOURCE
822
RESTART ISW DECODING
818

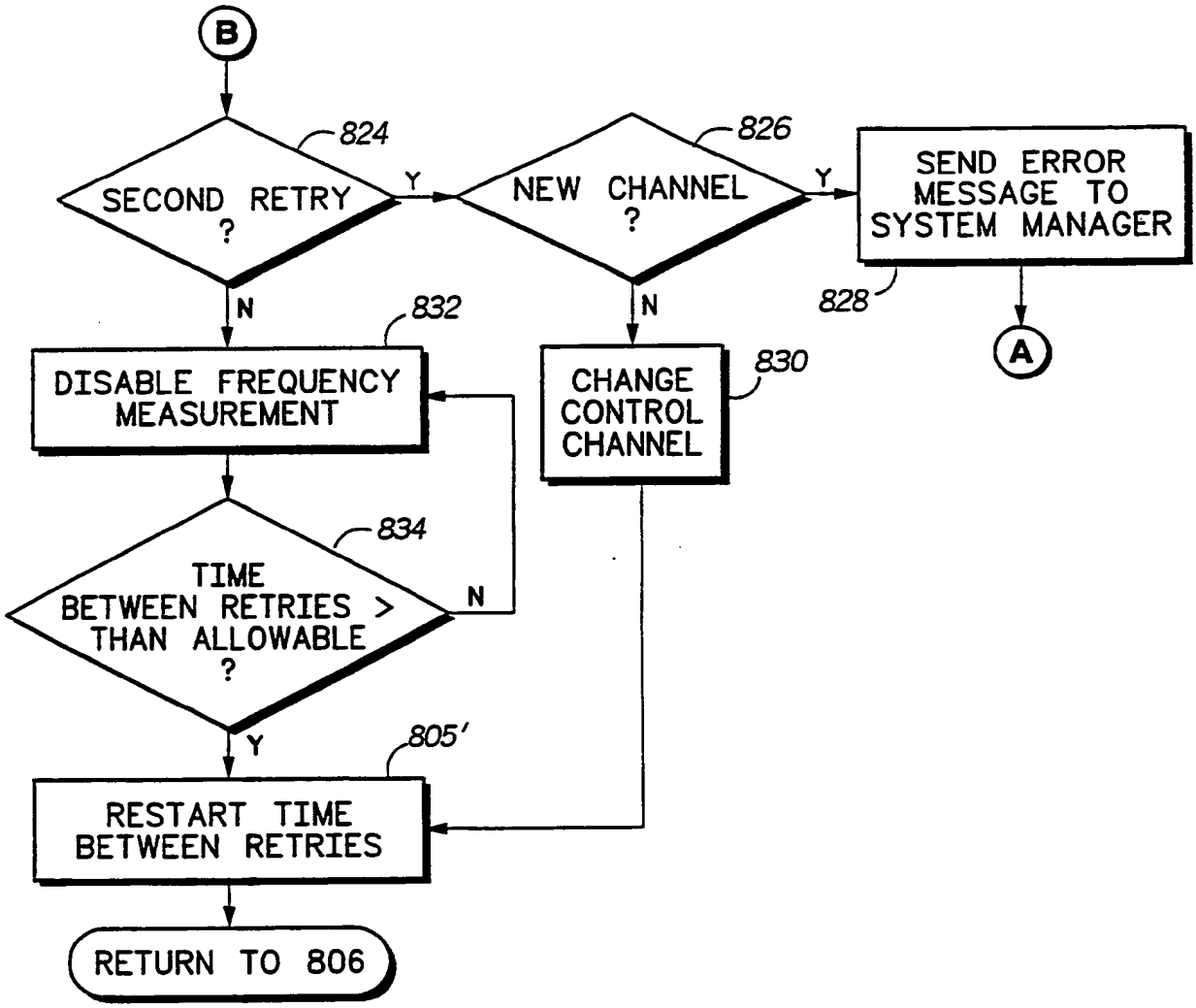

B
824
SECOND RETRY ?
Y
826
NEW CHANNEL ?
Y
SEND ERROR MESSAGE TO SYSTEM MANAGER
828
A
N
N
832
DISABLE FREQUENCY MEASUREMENT
CHANGE CONTROL CHANNEL
830
834
TIME BETWEEN RETRIES > THAN ALLOWABLE ?
N
Y
805'
RESTART TIME BETWEEN RETRIES
RETURN TO 806

FIG. 6b

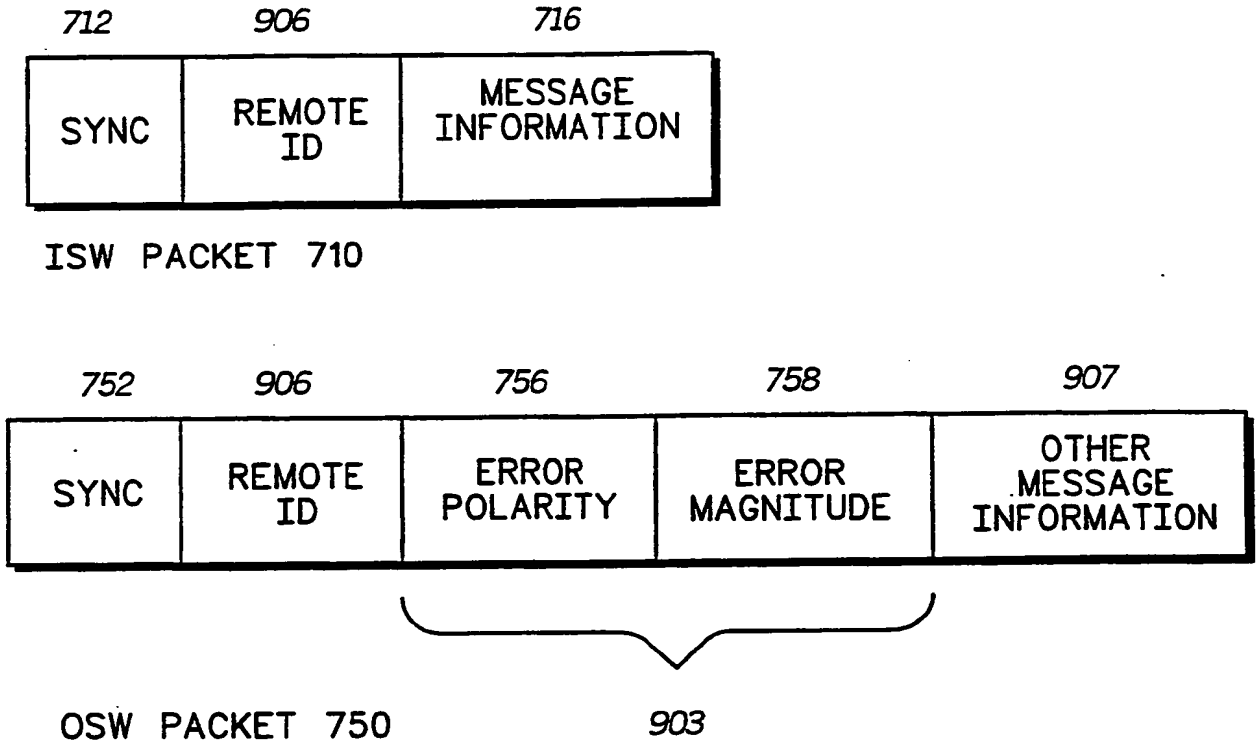

712
906
716
SYNC
REMOTE ID
MESSAGE INFORMATION
ISW PACKET 710
752
906
756
758
907
SYNC
REMOTE ID
ERROR POLARITY
ERROR MAGNITUDE
OTHER MESSAGE INFORMATION
OSW PACKET 750
903

FIG. 7

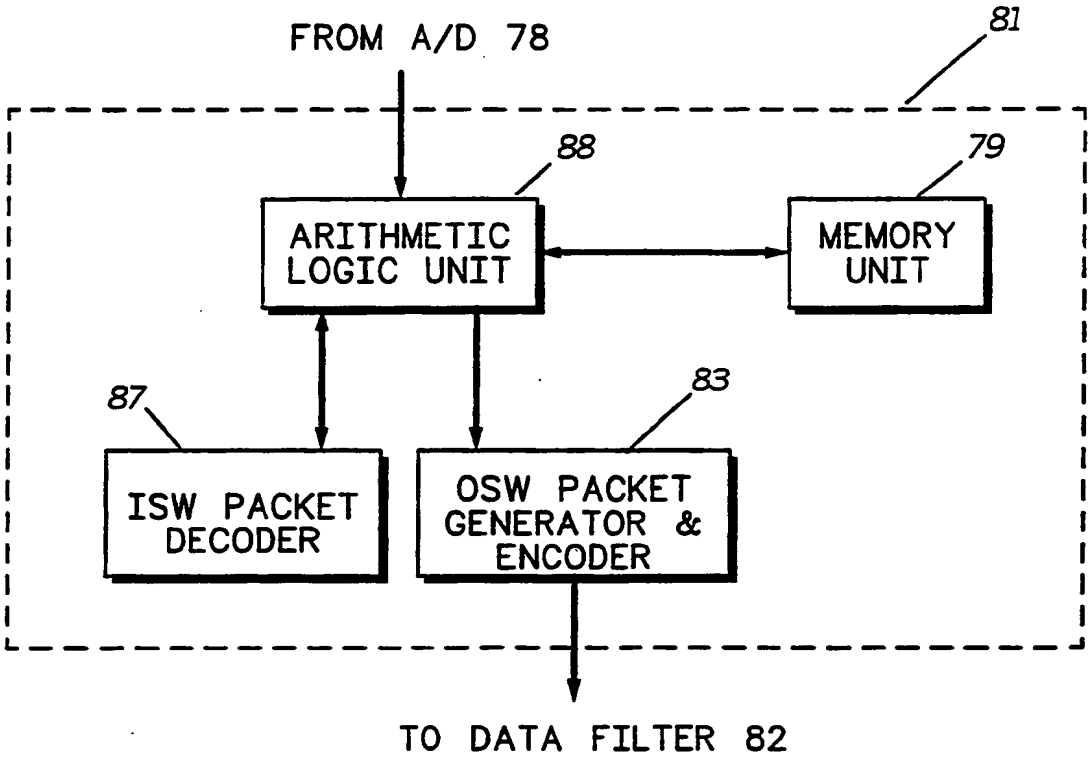
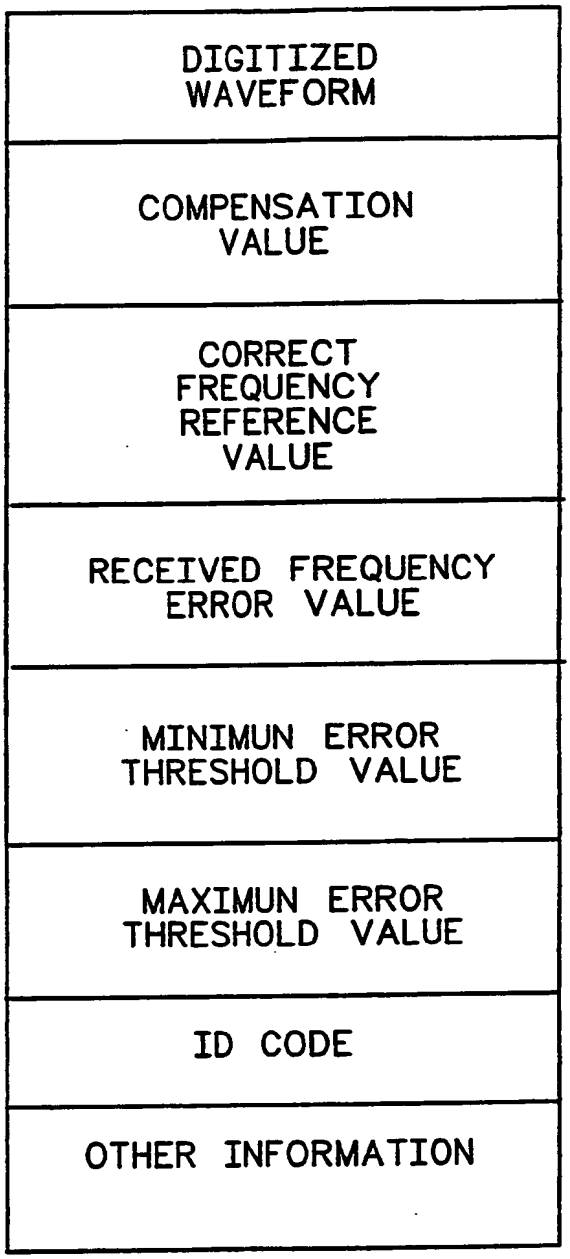

FROM A/D 78
81
88
79
ARITHMETIC LOGIC UNIT
MEMORY UNIT
87
83
ISW PACKET DECODER
OSW PACKET GENERATOR & ENCODER
TO DATA FILTER 82

FIG.8

FIG. 9


DIGITIZED WAVEFORM
900
COMPENSATION VALUE
901
CORRECT FREQUENCY REFERENCE VALUE
902
RECEIVED FREQUENCY ERROR VALUE
903
MINIMUN ERROR THRESHOLD VALUE
904
MAXIMUN ERROR THRESHOLD VALUE
905
ID CODE
906
OTHER INFORMATION
907

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/00748

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :HO4B 1/00, 17/00
US CL :455/54.2,67.1,71
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/54.1,67.4,68.183,186

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A 4,670,889 (HEWITT) 02 JUNE 1987 SEE ENTIRE DOCUMENT	1-10
A	US,A, 4,401,860 (WALLS) 30 AUGUST 1983 SEE ENTIRE DOCUMENT	1-10
A	US,A 4,932,072 (TOKO) 05 JUNE 1990 SEE ENTIRE DOCUMENT	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
14 AUGUST 1992	15 SEP 1992
Name and mailing address of the ISA/ Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer CHI PHAM
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